

THE NET-WINGED MIDGES (BLEPHAROCERIDÆ) OF NORTH AMERICA.

BY VERNON L. KELLOGG.

CONTENTS.

PLATES XVIII-XXII.

	PAGE
I. INTRODUCTION.....	187
II. DESCRIPTIONS OF NEW SPECIES, WITH IMMATURE STAGES.....	189
III. RELATION OF THE NEW SPECIES TO THE KNOWN, WITH SUGGESTIONS FOR A REVISION OF THE GENERA, AND ANALYTICAL TABLES OF NORTH AMERICAN GENERA AND SPECIES.....	196
IV. NOTES ON THE STRUCTURE OF LARVÆ AND IMAGINES.....	202
V. NOTES ON THE HABITS OF LARVÆ, PUPE AND IMAGINES.....	211
VI. SUGGESTIONS FOR WORK TO BE DONE.....	220
LITERATURE CITED.....	223
EXPLANATION OF PLATES.....	224

I. INTRODUCTION.

THE flies belonging to the family Blepharoceridæ, or net-winged midges, have long been of peculiar interest to entomologists because of the small number of known species and their supposed rarity, because of the wide and discontinuous distribution of these known forms, because of the remarkable aquatic life of larvæ and pupæ, and the strange modification of the body in both these stages in conformity with the curious habits, and because of the unique pseudo-net-veining of the wings of the imagines, produced by a series of folds in the wing membranes. In a recent paper (Kellogg, 1900) the writer has called attention to further interesting structural conditions in both larvæ and adults, especially the composition of the compound eyes of the imagines of two sizes of ommatidia, with differences in disposition of the retinal pigment, etc., resulting in a certain accommodation to different intensities of light.

There are at present to the writer's knowledge but fifteen¹

¹ Bezzi, in a paper describing the female of *Hapalothrix lugubris*, in Zeitsch. f. Hym. u. Dipt., 1901, and seen by the writer only after this paper had been sent to the printer, states that eighteen species are known.

Blepharocerid species (the new species described in this paper not included), representing ten genera, known in the world. Of these, five species, representing four genera, are found only in North America, north of Mexico; six species, of four genera, are found only in Europe; three species, of three genera, are South and Central American; and a single species is recorded from Ceylon. But one species extends its range outside of a single continent, although two genera are represented by both European and North American species. A discussion of the relationships of these widely scattered forms is included as part of this paper.

The immature stages of three of these fifteen known Blepharocerid species have been described, viz.: *Liponeura breviostris* (Europe) by Dewitz (1880) and Wierzejski (1881), *Curipara torrentium* (Brazil) by Fritz Müller (1881), and *Blepharocera capitata* by Comstock (1895) and the writer (Kellogg, 1900).

In this present paper the writer presents the descriptions of four new North American species found by him in the mountains of California, and, in addition, an account of the immature stages of each of these new species. The descriptions of the larval stages of at least two more species whose adult stages are not yet known are also presented; and the descriptions of larva and pupa of a species previously known only in the adult stage. In a discussion of the relationships of the North American species a table or key for the determination of these species is given, and also an account of an interesting series of modifications of the venation. The new species throw much light on what has been a puzzling venational condition in the hitherto known forms. There is also presented an account of some of the interesting structural characters of the larvæ and imagines, especially those of the larval suckers, the remarkable and suggestive condition of the compound eyes of the adult, the imaginal mouth-parts, etc. There is given also an account of the habits and life-history of the flies as far as known, with an account of the local and continental distribution of the North American species. Finally, a

statement has been added of the more serious deficiencies in our knowledge of the Blepharoceridæ, and some suggestions for the help of those who may be sufficiently interested to undertake the work of filling up some of these gaps.

II. DESCRIPTIONS OF NEW SPECIES.

Of the four new species from California here described, two are plainly to be ascribed to the genus *Blepharocera*, of which the European species *B. fasciata* is the type species, while the other two cannot be assigned to any one of the other Blepharocerid genera as at present defined, although both ought to be included in a single genus. With a slight modification of the genus *Bibiocephala*, erected in 1875 by Osten-Sacken for the single Colorado species, *B. grandis*, the two new species can be fairly included with *B. grandis* in a single genus. And this seems preferable to establishing a new genus for them. As a matter of fact, Osten-Sacken, having but a single species in his genus *Bibiocephala*, goes so far in defining the genus that he included in his generic diagnosis what are, in the light of the new forms, better looked on as specific characters. In addition to Osten-Sacken's species and the two here mentioned, the genus *Bibiocephala* as thus widened would also include von Röder's genus *Agathon*, established in 1890 for the single Nevada species *A. elegantulus*, found also by Aldrich in Idaho and by the writer in Colorado. This relationship of species is discussed in some detail in a succeeding portion of this paper.

1. *Blepharocera jordani*, sp. nov.

PLATE XVIII, FIG. 1; PLATE XIX, FIG. 3; PLATE XX, FIGS. 1 AND 2.

Eyes (Pl. XVIII, fig. 1) of both male and female bisected and nearly contiguous; the upper part of each eye is composed of larger ommatidia (apparent externally in the larger corneal facets) than the lower part; in the female the upper part of the eyes is larger in proportion to the lower part than in the male, and is prominent and bulging; in both sexes the upper

part of the eyes is red-brown, while the lower part is blackish; antennæ about twice as long as head, composed of fourteen segments; forelegs of female much shorter than middle and hind legs; not so in male; in both sexes middle legs nearly as long as hind legs; hind tibiæ with a pair of small spurs, fore and middle tibiæ without spurs; wings (Pl. XIX, fig. 3) with venation as in *Blepharocera fasciata* (Europe) and *capitata* (northeastern North America), that is, with M_3 incomplete (incomplete vein in the hind margin), no cross-vein between media and cubitus (no cross-vein between veins four and five), and R_2 wholly fused with R_3 (second vein simple, without branch); body not hairy, and pale fuscous in color without special markings.

Length, male 10 mm.; female 11-12 mm.

One free-flying adult male, San Francisquita Creek, near Stanford University, May 19, 1901; and numerous males and females dissected out from pupal cases, the specimens being fully developed and ready to issue; taken in April, May, and June, 1900 and 1901, from Corte de Madera, San Francisquita, Los Trancos, Steven's, Campbell's and Los Gatos creeks, all in the Sierra Morena and Santa Cruz mountains, within twenty miles of Stanford University, California; and in Smith's Creek (Mount Hamilton) and Coyote Creek (near Gilroy Hot Springs) in the Coast Range, at thirty-five and sixty miles respectively from Stanford University, California.

This distribution is practically the same as that so far determined for the species *Bibiocephala comstocki* and *Bibiocephala doanei*. Named for Dr. David Starr Jordan.

Immature Stages. The larvæ (Pl. XX, figs. 1 and 2) are, when full grown, 7 mm. to 9 mm. long; the lateral processes are short and inconspicuous; there are no strong markings, the whole body being mostly pale and comparatively soft (*i. e.*, not strongly chitinized); the dorsal surface of each segment bears traces of an incomplete quadrangular, blackish patch; the markings of the head consist of a median patch bearing a central triangle and two diagonal lines on each side of it, and a pair of lateral patches.

The pupa measures from 5.5 mm. to 6.5 mm. in length, is black, and is characterized by having its dorsal prothoracic respiratory plates markedly curving inward, so that the tips nearly or quite meet, the inner margin of the plates being thus strongly concave. The plates themselves are rather broad (as contrasted with the similarly inward curving but narrow plates of *Bibiocephala doanei*).

Both larvæ and pupæ of *B. jordani* are found commonly associated with the larvæ and pupæ of *Bibiocephala comstocki* and *B. doanei*.

2. *Blepharocera osten-sackeni*, sp. nov.

PLATE XVIII, FIG. 2; PLATE XIX, FIG. 2; PLATE XX, FIGS. 3 AND 4.

Eyes of female contiguous, and bisected by an unfacetted stripe; eyes of male separated by a considerable space, and bisected by a line, the upper or large-facetted portion including a much larger part of the eye in the females than in the males, this part in the male (Pl. XVIII, fig. 2) being unusually small (as compared with other species); antennæ a little more than twice as long as head, 14-segmented; forelegs not much shorter than middle legs either in female or male, hind tibiæ with spurs, others without, unguis strong and with a few longish spiny hairs at base; wings (Pl. XIX, fig. 2) with typical venation of *Blepharocera*, that is, with M_3 incomplete (incomplete vein in the hind margin), no cross-vein between media and cubitus (no cross-vein between veins four and five), and R_2 wholly fused with R_3 (second vein simple without branch); body without special markings, pale fuscous.

Length, male 4.5 mm.; female 5.6 mm.; the smallest member of the family so far known.

Described from several males and females dissected from pupal cases (these specimens certainly showing all the characteristic imaginal characters except, perhaps, the coloration; also they may not show quite the full length, *i. e.*, size, of free-flying specimens.

Collected near Mount St. Helena, Napa County, California; larvæ and pupæ taken also from a tributary of the North Fork of the Salmon River, near Sawyer's Bar, Humboldt County, California, and from near Castella, Shasta County, California; all of these localities being in the northern third of the State. There are also a few specimens of this species taken from the stomachs of trout from Battle Creek, California. Named for Baron von Osten-Sacken.

Immature Stages. The larvæ (Pl. XX, figs. 3 and 4) when full grown are 5-6 mm. long; dorsal surface of body dark, with transverse sutures between the segments broadly whitish, and a whitish spot near the lateral margin of each segment, giving the effect of an interrupted, broad, whitish, longitudinal line along each side of the body; these markings are in some specimens accented so that a strong black and white pattern is formed; in others the whitish is nearly lacking, so that the whole dorsal aspect is nearly uniform blackish; ventral aspect white with the suckers black; lateral processes short; single, and dark-colored.

The pupæ are about 4 mm. long, thus being conspicuously smaller than the known pupæ of any other *Blepharocera*. The prothoracic dorsal respiratory plates are rather broad and incurved.

3. *Bibiocephala comstocki*, sp. nov.

PLATE XVIII, FIGS. 6 AND 7; PLATE XIX, FIG. 6; PLATE XX, FIGS. 5 AND 6; PLATE XXI, FIG. 4.

Eyes (Pl. XVIII, figs. 6 and 7) of both male and female separated by a narrow space, and bisected by a narrow unfacetted stripe; upper, large-facetted portion of each eye larger in proportion to rest of eye in female than in male, antennæ twice as long as head or a little more, 14-segmented, the two basal segments annulated with white; hind legs longer than the subequal middle and fore legs, the hind tibiæ with spurs, other tibiæ without spurs, the unguis strong and with the basal half bearing numerous short, fine hairs; wings (Pl. XIX, fig. 6) with a cross-vein between media and cubitus (cross-vein connecting veins four and five) and with R_2 distinct for a short distance but running into R_1 about one-third of the distance from the origin of R_2 to the tip R_1 (second vein with a short anterior branch which begins proximad of the origin of the third vein, and which runs into the first vein about one-third of the distance from the origin of the second vein to the tip of the first vein); a faintly indicated subcostal vein (auxiliary) is apparent, which extends about half the length of the costal margin; body covered with fine blackish pile.

Length, male 7.5-8.5 mm.; female 9-10 mm.

Described from one free-flying male, Campbell Creek, near Congress Springs, Santa Clara County, California, April 6, 1900, and from numerous males and females dissected out of pupal cases taken from Los Gatos, Corte de Madera, Stevens, Alembique, Los Trancos, and Campbell creeks, and from Bear Gulch, from March to May, 1900 and 1901—all these streams being in the Santa Morena and Santa Cruz mountains, within twenty miles of Stanford University, California. Named for Professor J. H. Comstock.

Immature Stages. The larvæ (Pl. XX, figs. 5 and 6) when full grown measure from 9 to 12 mm. in length; dorsal surface of the body pale ground-color, with a broad, transverse darkish bar, usually indistinctly outlined on each body segment; near the middle of each segment a pair of small black spots always present, though sometimes rather faint; lateral processes double, not very long, the anterior one of each pair being the longer and slenderer, and blackish all over, the posterior one being dark brown below and whitish above; the ventral suckers unusually small, the antennæ unusually long; the tufts of tracheal gills consisting of four tubules each.

The pupæ (Pl. XXI, fig. 4) are from 7 to 8 mm. long, black (not dark brown) and with short, broad, prothoracic respiratory plates, the two groups of plates being set more closely together than usual with Blepharoceric pupæ.

4. ¹*Bibliocephala elegantulus* von Röder.

PLATE XVIII, FIGS. 4 AND 5; PLATE XIX, FIG. 5; PLATE XX, FIGS. 9 AND 10; PLATE XXI, FIG. 7; PLATE XXII, FIGS. 7 AND 8.

Eyes (Pl. XVIII, fig. 5) of male separated rather widely, and bisected by a narrow line, the upper, large-faceted portion of the eye being one-fourth of the whole eye; in female (Pl. XVIII, fig. 4) the eyes are separated by a narrow space, and bisected by a line, the upper, large-faceted portion forming about one-third of the whole eye; antennæ 14-segmented, and about one and one-half times as long as head; hind legs longer than subequal middle and fore-legs, hind tibiæ with spurs, middle tibiæ with very small spurs, fore tibiæ without spurs, unguis rather strongly curved, not incrassate; wings (Pl. XIX, fig. 5) with a cross-vein between media and cubitus (connecting veins four and five) with R_2 present as a very short vein running so quickly into R_1 as to form a nearly equilateral triangle (a short anterior branch of the second vein running into the first vein close to the origin of the second vein); R_3 and R_4 usually arise from a common point but are not stemmed, a short stem, however, sometimes being present, and in this case there may be a cross-vein connecting the two near the point of forking (veins two and three usually sessile but occasionally having a very short stalk); a short subcostal vein (auxiliary) is usually indicated; dorsal and lateral aspects of thorax dark brown, ventral aspect whitish; dorsal aspect of abdomen dark brown, with narrow, transverse sutural lines, ventral aspect whitish; legs pale brown; antennæ and head except the red-brown, upper, large-faceted portion of eyes blackish.

Length of male 8.5 mm.; female 10 mm.; body of female (Pl. XXI, fig. 7) much more robust than in male.

Described from numerous free-flying males and females taken in July and August, 1900, from Big Thompson River, at the mouth of Willow Park, altitude 7,500 feet, in Estes Park, Larimer County, Colorado; same species found also in Wind River, Mill River, and South Fork, streams tributary to the Big Thompson. Originally described by von Röder as a new genus, *Agathon*, from Nevada. Aldrich has found it in Idaho.

¹ In the paper as sent to the printer, the writer had described this as a new species, being led to do this by von Röder's contradictory account of the venation of *Agathon*. Von Röder's account deceived also Osten-Sacken and Williston, who thus wrongly enter *Agathon* in their synoptic tables. Professor Aldrich, however, called the writer's attention to the fact that although von Röder uses the word "*pone*" instead of "*ante*" in his Latin description of the species, in his German description of the genus the contrary (and true) condition is properly described. Von Röder also unfortunately gives an ambiguous locality for his species in the words "Patria: (Sierra) Nevada, America septentr. (Morrison)." In a letter to Professor Aldrich, Baron von Osten-Sacken states that Morrison found the specimens in the State of Nevada and not in the Sierra Nevada (mountains of California).

Immature Stages. Larvæ (Pl. XX, figs. 9 and 10) red-brown above, with four small but distinct black spots on dorsum of each body segment; lateral processes rather pronounced, double, the anterior one of each pair angulated, both processes dark brown; tracheal gill-tufts composed each of four tubules, two projecting anteriorly and two posteriorly; antennæ rather short, length 6-8 mm.

Pupæ black, with short, broad, slightly curving, dorsal, prothoracic respiratory leaves; length 7 to 8 mm.

5. *Bibiocephala doanei* Kellogg.

PLATE XVIII, FIG. 3; PLATE XIX, FIG. 4; PLATE XX, FIGS. 7 AND 8;
PLATE XXI, FIG. 3; PLATE XXII, FIGS. 9, 10 AND 11.

Liponeura doanei KELLOGG, Psyche, Vol. IX, 1900, p. 39.

This species, the first of the new Californian species found, was first described as a *Liponeura*, but in the light of the other forms the species should be removed to the genus *Bibiocephala*. For the purpose of making this paper complete, the essential parts of the description as already published are repeated here, and the description of the male and of the immature stages are added. At the time of describing the species, only the adult females were at hand in condition for description.

Female.—Length 6 mm.; length of wing 7.5 mm.; very pale brown, almost clayey; antennæ 14-segmented and rising from a prominence which might be construed as a basal antennal segment; eyes broadly separated, and with no indication of bisection, the facets being all of the same size; eyes in the male (Pl. XVIII, fig. 3) broadly separated, and bisected by a distinct line; the mouth-parts (Pl. XXII, figs. 9, 10 and 11) long (distinctly longer than in *Blepharocera*, for example); wings with venation (Pl. XIX, fig. 4) showing the following characters, vein M_3 independent, *i. e.*, without connection with M or any other principal vein (an incomplete vein running into the posterior margin between veins four and five); vein R_2 present as a very short spur running so quickly into R_1 as to form a small triangle with R_2 as the shortest leg (a short anterior branch of the second vein running into the first vein close to the origin of the second vein); a medio-cubital cross-vein (a cross-vein between veins four and five); veins R_2 and 3 and R_4 and 5 separating at the origin of the radio-medial cross-vein (the submarginal cell sessile); the radial sector springing from R by two roots (the cross-vein between veins one and two Y-shaped, *i. e.*, the anterior half of it divided, enclosing a small triangular cell); subcosta wanting or with only a basal rudiment present (auxiliary vein wanting or with only a basal rudiment present); wings clear, with strong iridescent reflections; legs long, the three pairs of about equal length,

the hind tibiæ bearing a single terminal spur, the other tibiæ without spurs; tarsal claws large, thick, and strong with curved, pointed tip, thickly pectinate except at the tip.

Described from two females and one male, taken by R. W. Doane, July 24, 1895, on the banks of a small stream in the Santa Cruz Mountains, at Congress Springs, Santa Clara County, California. In addition, the writer has dissected practically adult males and females from pupal cases found during February, March, and April, 1900 and 1901, in Los Gatos, Campbell, Stevens, Los Trancos and Corta Madera creeks—all in the Santa Cruz and Santa Morena mountains, within twenty miles of Stanford University, California. The writer has also taken specimens in Coyote Creek, near Gilroy Hot Springs (April), in the Coast Range; and G. A. Coleman collected larvæ and pupæ in Red Cap Creek, Hoopa Indian Reservation, Humboldt County, California, July 26, 1901. Named for Mr. R. W. Doane.

Immature Stages. Larvæ (Pl. XX, figs. 7 and 8) rather broad and short, with strongly chitinated dorsal body-wall; each segment, except the head and thoracic segment with one, with two rough, black, transverse bars; lateral processes rather conspicuous, double, the anterior member of each pair the longer, and with hairs at its tip; tracheal tufts composed of six tubules, two of which project laterally, the others anteriorly; length 7 mm.

Pupa (Pl. XXI, fig. 3) black, with narrow, high, incurving respiratory plates, the two members of the pair being set widely apart; length 6 mm.

Larvæ of Two Additional Species.

In addition to the five Blepharocerid species just described, the writer has found the larvæ of two additional species whose pupæ and adults have not yet been found. As both of these larvæ, one found in Colorado and one in California, present external features of particular interest, they are here figured and the following brief descriptions of them are given, without, of course, offering names for the species; it may be, indeed, and is to be hoped, that the Colorado one is the larvæ of Osten-Sacken's *Bibliocephala grandis* (described by him from Colorado), and the

California one the larva of his *Blepharocera ancilla* or *Liponeura yosemite* (both described from California).

New Colorado Larva (Pl. XX, figs. 11 and 12). Short and broad; dorsal aspect blackish, rugose, strongly chitinized; lateral processes long and prominent, double, and both members of each pair provided with numerous hairs; the anterior member of each pair longer, angulated, and bearing at its tip a very long, spiny hair; these lateral processes pale fuscous in color; the tracheal tufts composed of six large tubules, three of which project anteriorly and three posteriorly; the ventral suckers unusually large, and larger than in any other Blepharocerid larva yet seen by the writer; the dorsum of the head and thoracic body segment elaborately marked with blackish, brownish and pale fuscous; on under side of this segment a lateral, longitudinal row of three conspicuous pale dots, each with fine black pin-point center; length 7 mm.

These larvæ were found in same places as those of *Bibiocephala elegantulus*, and were quite as common.

New California Larva (Pl. XXII, figs. 1 and 2). Short and broad; brownish above, elsewhere pale yellowish white, the dorsal aspect of posterior body segment also pale yellowish white with blackish posterior margin; lateral processes double, long, and fringed with numerous hairs; the anterior process of each pair longer, not angulated, and darker above than posterior one; these processes longer than in any other Blepharocerid larva known to the writer; antennæ unusually long; tracheal tufts composed of four tubules, all projecting anteriorly; length 5.5-6 mm.

These larvæ were found scatteringly and rarely in most of the streams, viz., Los Gatos, Campbell, and Alembique creeks, etc., near Stanford University, in which were found *Bibiocephala comstocki* and *B. doanei*.

III. DISCUSSION OF THE CLASSIFICATION OF THE NORTH AMERICAN SPECIES.

The whole family Blepharoceridæ is readily divisible into two groups, of which one, characterized by the absence in its members of a short incomplete vein near the posterior margin of the wing, includes six genera, each represented by a single species, none of which is found in North America north of Mexico. These six genera and their distribution are *Apistomyia* (Corsica, Cyprus), *Hapalothrix* (Monte Rosa, Switzerland), *Hammatorhina* (Ceylon), *Curipara* (Province St. Catharina, Brazil), *Snowia* (Rio

Janeiro, Brazil), and *Paltostrongylus* (Columbia, South America, Mexico and West Indies).

The remaining known species are grouped, in the latest revision (Osten-Sacken, 1895) of the family, into four genera, of which two, *Bibiocephala* and *Agathon*, each with a single species, are recorded only from the western United States, while the other two, *Blepharocera* and *Liponeura*, with respectively three and four species each, have representatives in both Europe and the United States. The species recorded from North America, according to this revision, are *Blepharocera capitata* (Northeastern United States and reaching far north), *Blepharocera ancilla* (California), *Liponeura yosemita* (California), *Bibiocephala grandis* (Rocky Mountains, Colorado), and *Agathon elegantulus* (Nevada). Of these species male specimens alone are known of *Bibiocephala*, *Agathon* and *Liponeura*; females alone of *Blepharocera ancilla*, and both sexes of *Blepharocera capitata*. In the light thrown upon the value of the characters used by Loew, Osten-Sacken, and von Röder in their establishment of genera, by the four new species described in this paper, of which males and females are known in every species, it becomes necessary to suggest a re-revision of the Blepharocerid genera. This suggestion is made with distinct reluctance, but the simple observation of the existing facts dictates it.

The contiguity or separation of the eyes, and their bisection, have been relied on as generic characters; but it is obvious from the conditions shown by the new species *Bibiocephala doanei*, in which the eyes of the male are bisected while those of the female are not, and from the condition of *Bibiocephala* (*Agathon*) *elegantulus*, where the males have the eyes separated by a broad space while the eyes of the female are subcontiguous, that such distinctions cannot distinguish genera, if, indeed, even specific value may be given them. On the other hand, an inspection of the venation of the wings shows that forms with identical venation or with variations amounting (as will be shown) simply to slight differences in degree, not in kind, have

been assigned to independent generic rank, while apparently important venational differences have not been allowed to interfere with the assignment of several species to a common genus.

By a careful inspection of the venational condition shown by all the so far known North American species (in the case of *Blepharocera ancilla* and *Liponeura yosemite* only the descriptions and figures of the wings were had for reference), it has seemed to be not difficult to suggest a classification based on these conditions, which is not open at least to the grave defects of a classification based on characters which are seen (in the newly-found forms) to vary with the sexes in a single species. As this revision tends to reduce the number of genera rather than increase it, its author cannot be charged with anxiety to revise for the sake of making new names! As a matter of fact, it is but following the excellent suggestion of Osten-Sacken, made in his revision (l. c., p. 160) in words as follows: "To those who will continue the work on Liponeuridæ [=Blepharoceridæ] I would humbly recommend, as a result of many years of experience, not to multiply the genera unnecessarily. * * * When in such decadent groups we multiply the genera too much they in the end become all monotypical, and thus baffle the pursuit of classification, as the survey of their mutual affinities becomes more difficult. The true end of classification is an easier survey of affinities, a temporary aid to the memory."

The changes suggested here are, briefly, that Osten-Sacken's genus *Bibiocephala*, erected for the single Colorado species *B. grandis*, be widened (by cutting out some of the specific characters of *B. grandis* included in the definition of the genus) so as to admit the new species *comstocki* (California) and *doanei* (California), described in this paper, and von Röder's species *elegantulus* (Colorado); that the genus *Blepharocera* be limited to and include all forms which have no distinct radius₂ (anterior branch of second vein) and which have no media-cubital cross-vein (cross-vein connecting veins four and five); and that

Liponeura include those forms without a distinct radius₂ (anterior branch of second vein) but with a media-cubital cross-vein (cross-vein connecting veins four and five). The type species of *Blepharocera* will continue to be *Blepharocera fasciata*, the common European Blepharocerid described by Westwood in 1842; and to this genus will belong the three American species, *B. capitata* Loew, *B. jordani* Kellogg, and *B. osten-sackeni* Kellogg, and the two European species now called *Liponeura cinerascens* Loew and *L. brevirostris* Loew. As *L. cinerascens* is the type species of the genus *Liponeura*, a new generic name will have to be given to those other species, *bilobata* Loew and *yosemite* O.-S., which were included with *L. cinerascens* in the genus *Liponeura*, but which cannot be transferred with *L. cinerascens* to the genus *Blepharocera*. The name *Philorus* (mountain-loving) is here suggested for these forms. Included with *bilobata* and *yosemite* in this genus *Philorus* would come Osten-Sacken's *Blepharocera ancilla*. By this arrangement von Röder's *Agathon elegantulus* should be included in *Bibiocephala*.

The following analytical tables will show the relation of the genera under the present suggested revision:—

ANALYTICAL TABLE OF GENERA OF NORTH AMERICAN BLEPHAROCERIDÆ.

- I. An incomplete media₃ lacking (=no incomplete vein near the posterior margin of the wings).

Apistomyia (Corsica, Cyprus), *Hammatorhina* (Ceylon), *Palto-stoma* (Columbia, Mexico, West Indies), *Snowia* (Rio Janeiro), *Curupira* (Brazil), *Haplothrix* (Monte Rosa, Europe).

- II. Media₃ present but incomplete (=an incomplete vein near the posterior margin of the wings).

(North American and European species.)

- A. Radius₂ partly distinct (=second longitudinal vein with two branches); a cross-vein between media and cubitus (=cross-vein connecting veins four and five).

Radius₂, radius₃ and radius₄ all separating at a common point or close together (=anterior branch of second vein, and veins two and three all separating at a common point or close together).

Bibiocephala (Pl. XIX, figs. 4, 5, 6 and 7).

- A. A. Radius₂ wholly fused with radius₃ (=second longitudinal vein simple, without branches).

B. No cross-vein between media and cubitus (=no cross-vein connecting veins four and five).

Blepharocera (Pl. XIX, figs. 1, 2 and 3).

B. B. A cross-vein between media and cubitus (=a cross-vein connecting veins four and five).

Philorus (Pl. XIX, figs. 8 and 9).

TABLE OF SPECIES OF BIBIOCEPHALA.

Eyes contiguous; r_2 running into r_1 near the margin of the wing (=anterior branch of second vein running into vein near margin of the wing); eyes bisected; fore femora of male strongly curved.

1. *B. grandis* O.-S. (Colorado, Utah, Idaho).

Eyes separated by a narrow or broad space, in both males and females; eyes bisected; fore femora of male straight.

Eyes of both male and female bisected.

Eyes of male separated widely; of female narrowly; r_2 running into r_1 (anterior branch of second vein running into first vein) very soon, forming a nearly equilateral triangle.

2. *B. elegantulus* von Röder (Nevada, Idaho, Colorado).

Eyes of both male and female separated narrowly; r_2 running into r_1 at about one-third of the length of the distance from origin of radial sector to the tip of r_1 (anterior branch of second vein running into first vein at about one-third the distance from origin of second vein to tip of first vein).

3. *B. comstocki*, sp. nov. (California).

Eyes of male bisected; of female not bisected; r_2 running into r_1 very soon, making a triangle in which r_2 forms the shortest side (anterior branch of second vein running into first vein very soon making a triangle in which anterior branch of second vein forms the shortest side).

4. *B. doanei* KELLOGG (California).

TABLE OF NORTH AMERICAN SPECIES OF BLEPHAROCERA.

Eyes of female contiguous, of male separated by broad space; length not over 6 mm.

1. *B. osten-sackeni*, sp. nov. (Northern California).

Eyes of both sexes separated by narrow space; length not less than 7 mm. Ungues slender and rather long.

2. *B. capitata* LOEW (Northeastern United States).

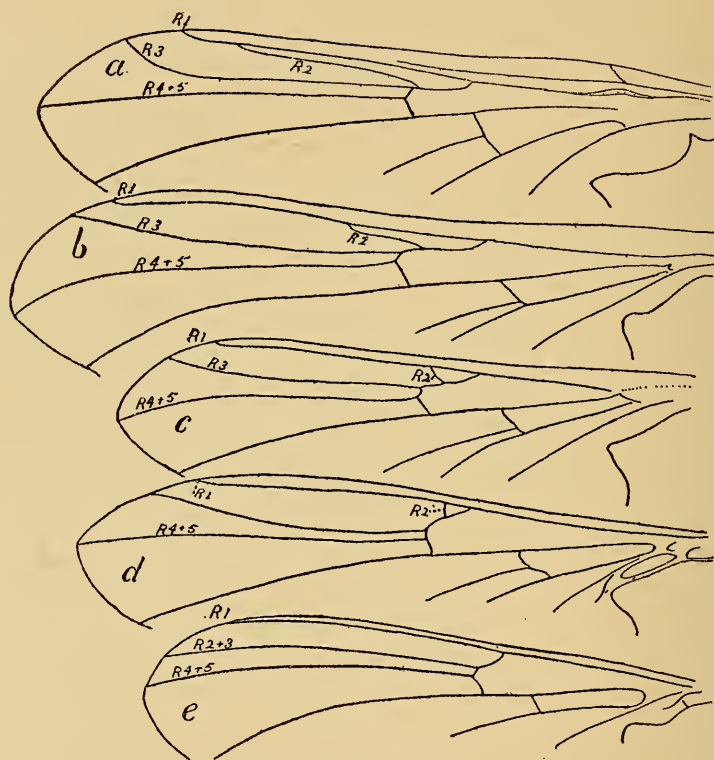
Ungues stout and shorter.

3. *B. jordani*, sp. nov. (California).

It seems unnecessary in the face of the descriptions and figures of the new species here recorded, and of the contrasting characters as indicated in the foregoing analytical tables, to argue for the soundness of this suggested revision, based on venation; or rather for the unsoundness of the old classification based on continuity and bisection of the eyes. It may indeed be necessary to revise again the generic classification when another half dozen species are found, but this further revision cannot possibly be based on eye characters; it will probably be based on venational characters. It is not a long step from a slightly free radius₂ (=anterior branch of second vein) as shown by *Bibiocephala doanei* and *B. elegantulus* to one wholly fused with radius₁ or radius₃ (with the first or second vein), as is the case in *Blepharocera* and *Philorus*. Indeed so obviously is this difference simply a matter of degree of serial modification or specialization that it is a question whether the species of *Philorus* and *Bibiocephala* should not be looked on as members of a single genus, distinguished from *Blepharocera* by the possession of a medio-cubital cross-vein (cross-vein connecting veins four and five).

The series formed by *Bibiocephala grandis*, *B. comstocki*, *B. elegantulus*, *B. doanei*, and *Philorus bilobata*, with regard to the addition of the radial vein as shown in text-fig. 1, is very suggestive. It is certainly a pretty demonstration of what that formerly mysterious little triangle, which was found and puzzled over in *Bibiocephala doanei* (see the original description of *doanei* as a *Liponeura* in Psyche, Vol. IX, pp. 39-41) really is.

This serial modification (by increasing fusion of one radial branch with another) has been elsewhere prettily shown by Comstock (Manual, pp. 442-443) after Winnertz, in the case of certain Mycetophilid species, in which a series almost exactly similar to the one just shown above is described, except that the fusing vein is not radius₂ but is a vein formed by the already complete fusion of radius₂ and radius₃.



TEXT-FIG. 1.

Fig. 1. Diagram showing the condition of the radial branches in (a) *Bibiocephala grandis*, (b) *Bibiocephala comstocki*, (c) *Bibiocephala elegantulus*, (d) *Bibiocephala doanei*, and (e) *Philorus bilobata*. These five species form a series in which radius₂ proceeds from a condition in which it is free for almost its whole length to a condition of complete coalescence, i. e. disappearance.

IV. NOTES ON THE STRUCTURE OF LARVÆ AND
IMAGINES.

The published notes on the structure of the Blepharoceridæ, in addition to the external details more or less superficially described in the specific descriptions of various authors, are included in the papers of Dewitz (1880), Müller (1881), and the writer (1898, 1899, 1900).

The suckers of the larvæ are described in more or less detail by all of these writers (in each case for a different species). For the sake of making this paper as nearly as may be, in brief compass, an introduction to the study of the North American Blepharoceridæ, there is here quoted part of the already published description, with the figures, of the suckers of the larvæ of *Blepharocera capitata* (Kellogg, 1900).

The body of the larva consists of six parts, separated by distinct constrictions. By making sagittal longitudinal sections through the body it can be seen that the anterior, apparently single, segment is composed of the fused head and three thoracic segments, while the most posterior part is composed of the last two abdominal segments, the intervening parts representing each a single abdominal segment. That the anterior body part comprises the head and thoracic segments is also proved by the fact that the imaginal discs of the legs and wings are to be found here. The larva is footless; but each body part (not body segment) bears a pair of small, unsegmented, pointed projections (Pl. XXI, fig. 6, *l. p.*), situated on the ventral aspect of the lateral margins. This projection may be of slight use to the larva in locomotion, but, at best, only of slight use. The real organs of locomotion and of attachment to the rock bed of the stream are the six "suckers," one of which lies on the median ventral aspect of each body part. There is but one sucker for the combined head and thorax, and but one for the last two abdominal segments. By means of these suckers the larva clings to the rock bed of the stream, despite the impact of the swiftly flowing water. The larva

can loosen its hold with the suckers voluntarily; and, by loosening those at one end of the body, swinging this end laterally and refastening it, and then loosening the other end of the body and swinging and refastening it, a slow but safe locomotion, chiefly lateral, is possible. The larvæ move about not a little, especially from the necessity of continually moving from the edge out farther into the stream as the water of the little stream gradually lessens in quantity.

The structure of these suckers and the manner of their working are of interest. The ventral (external) aspect of a sucker (Pl. XXI, fig. 5) shows a central opening, surrounded by a strong, flexible, concave rim, marked with alternating concentric thicker and darker and thinner and lighter bands of chitin. The rim projects considerably ventrad, so that a considerable free or air space is enclosed by the rim when its outer edge is applied to any surface. In dorso-ventral sections transversal to the body of the larva (Pl. XXI, fig. 6), the whole structure of the sucker is apparent. The cup-shaped sucker is seen, after all, not to consist of a rim around a circular opening, but to be simply a part of the outer body-wall (true skin and chitin cuticula) peculiarly folded and modified to act as a sucker. The projecting cup-like part of the sucker is coated with chitin, so as to be thick and strong, although still flexible. At its base the skin is almost free from chitin, thrown into fine folds, and bent in toward the interior of the body and then out again. Here it is greatly thickened by a circular, lens-shaped deposit of chitin, which is slightly larger than the inner neck of the sucker, which it closes internally. The neck of the sucker is the apparent central opening, and the lens-shaped thickening is the bell-shaped structure, which closes this opening internally, as seen in looking at the sucker from the under or external side. The structure of the sucker is all plainly shown in Pl. XXI, fig. 6, and can be much more readily understood from an inspection of the figure than from reading this description. Attached to the inner face of the lens-shaped "stopper" of the sucker are two great muscles which run dorsally and

somewhat diagonally clear through the body-cavity to the dorsal walls, to which they are attached. The muscles do not rise directly from the “stopper,” but are fastened to it by strong, short tendons. The manner of the sucker’s functioning can now be understood. With the rim resting on a smooth surface, the rock bed of the stream, and the “stopper” well down in the neck of the air-cavity of the sucker, the lifting muscles may be contracted, the “stopper” raised (the folds at the neck give chance for a considerable movement of the “stopper”), and a partial vacuum formed with the sucker. What muscles are used when the insect desires to loosen the hold of a sucker is not so evident. Probably the contraction of certain dorso-ventral muscles which lie lateral of the muscles which lift the “stopper” serves to force the “stopper” down by flattening the body dorso-ventrally. So firmly can the larvæ hold to the rock bed by means of these suckers that one often tears a larva in two in attempting to remove it.

Imaginal Mouth-parts (Pl. XXII, figs. 9, 10 and 11). In the imago the structural conditions of special interest are those presented by the mouth-parts and the eyes. The following account, with the figures of the mouth-parts of *Bibiocephala doanei* Kellogg, is taken from *Psyche*, Vol. IX, 1900, pp. 39-41:

The mouth-parts of the female consist of the following well developed, independent, and easily distinguishable parts shown in Pl. XXII, fig. 9, *in situ* to reveal the relative size and natural position with regard to each other; a labrum-epipharynx (*l. ep*), a pair of mandibles (*md*), a pair of maxillæ (*mx*), a labium (*li*) and a hypopharynx (*hyp*).

The labrum-epipharynx is elongate, slender, and pointed, and bears numerous taste-pits (?) on its lower (inner) surface, which is concave.

The mandibles are long, slender, well chitinized, and each is sharply, finely, and conspicuously serrate along the distal half of the inner margin. The mandibles are articulated with the head-capsule, wholly distinct from the other mouth-parts.

The maxillæ consist of a single short, tapering, blade-like, thin but well chitinized maxillar lobe, and a long, slender, five-segmented palpus. Lobe and palpus arise from a basal sclerite, which shows no differentiation into cardo and stipes, and may be taken to represent these two sclerites completely fused.

The labium consists of a strong, elongate, basal sclerite which presents indications of a line of fusion of submentum and mentum, and a pair of free, fleshy, terminal lobes, the paraglossæ. These terminal lobes have no pseudo-tracheæ. There are no palpi.

The hypopharynx is as long or slightly longer than the labrum-epipharynx, is narrower, and although thin, well chitinized. It lies along the dorsal surface of the labium, underneath the labrum-epipharynx.

The mouth-parts, excepting the mandibles, are carried somewhat forward by the extension of their bases or of the frontal part of the head-capsule. The various parts of the mouth dissect apart readily.

In *Blepharocera capitata* Loew a similar condition of the mouth-parts exists, as may be seen from the following account taken from Entomological News (Kellogg, 1900) :

"The females of *Blepharocera*, like the females of *Simulium*, *Ceratopogon*, *Dixa*, *Culex*, and some other Nematocera, are blood-sucking, and while the mouth-parts of these forms are not strictly biting, the mandibles are present, as cutting or sawing or piercing organs. The males of these forms are nectar-feeding, and have lost the mandibles. In the mouth-parts of the female *Blepharocera* all of the parts of the typical biting mouth are present, the mandibles, maxillæ and labium. The mandibles are long and serrate on their inner edges, so as to be effective lacerating instruments. The maxillæ are elongate and blade-like and have four-segmented palpi. The labium is, though somewhat elongated, truly tip-like, and has its terminal lobes not coalesced and without pseudo-tracheæ. The hypopharynx is not short and tongue-like, as in the orthopterous mouth, but is long and slender and stylet-like.

Altogether the difference between the mouth-parts of *Blepharocera* and the typical biting type is one of modification, and of modification not sufficient to obscure the homologies, although a modification more profound than that shown by the most generalized Lepidoptera or Hymenoptera. On the other hand, there is not much difficulty in tracing the development of the dipterous mouth from the generalized condition of *Blepharocera* (or *Simulium*, or *Dixa*, *et al.*) to that extraordinary specialized condition shown by *Musca*, where the mandibles and maxillæ are lost, and the labium is so modified that it has no longer any likeness to the 'lower lip' of the orthopterous mouth."

Although it has seemed from a comparative study of the imaginal mouth-parts of all the nematocerous (generalized) families of Diptera (excepting the Ornephilidæ) and of most of the brachycerous (specialized) families, that the homologies of the mouth-parts can be satisfactorily determined, certain entomologists have refused to recognize the determination of homologies thus based to be conclusive. With this in mind, and recognizing, indeed, the general desirability of testing by ontogenetic study any conclusions arrived at from comparative anatomical study, the writer has studied the post-embryonal development of the mouth-parts of representatives of two of the nematocerous families of Diptera, the Simulidæ and Blepharoceridæ, whose females are equipped with what are here said to be all the recognized parts of the generalized orthopterous, or typical biting mouth. These parts are indeed much modified, the mandibles in particular being oddly elongated and serrated to form a pair of rasping knives, or saws, with which the body of the prey (smaller insects, especially Chironomids) is lacerated so that the blood and body juices may be sucked.

In this study, the results of which are published elsewhere in connection with studies of the development of the imaginal mouth-parts of other orders of insects with complete metamorphosis (Kellogg, 1902), it has been possible to trace the development of the imaginal parts within the head of the

larvæ from beginning to complete condition, and to ascertain that the correspondence between the greatly modified parts of the adult mouth, adapted for lacerating and lapping or sucking, and the generalized biting parts of the larva can be satisfactorily established, mandible for mandible, maxilla for maxilla, and labium for labium. In the larval mouth the homologies of the parts with the parts in the biting orthopterous mouth are apparent. They can be traced, of course, in their embryonic development from budding appendages to completed larval mouth-parts, leaving no possible doubt of their homologies; and this has been done for *Simulium* by Metschnikoff. As the eggs of the Blepharoceridæ are as yet unknown, this embryonic tracing cannot yet be done.

Imaginal Eyes (Pl. XXII, fig. 1). With regard to the curious condition of the eyes of the adult Blepharocerids, the following is taken from the account in the Entomological News (Kellogg, 1900) of the eyes of *Blepharocera capitata*.

The other specially interesting point in the imaginal anatomy of *Blepharocera* is the structural condition of the compound eyes. It has long been observed that several flies (*Simulium*, *Tabanus*, *et al.*) and certain other insects (Libellulidæ, *Ascalaphus*, Ephemeridæ, *et al.*) have two sizes of facets in each compound eye; that some have the field containing these differently sized facets well delimited, the fields being in some cases actually separated from each other by a non-facetted line or by a constriction. When this constriction is so complete that the eye is truly divided, it may fairly be said that there are two pairs of compound eyes, the two eyes of each lateral pair differing in the size of the facets. This last extreme condition exists in the case of the males of certain Ephemeridæ and in both males and females of *Blepharocera capitata*. [And in almost all other Blepharocerid species. See Pl. XVIII, all figures.]

The eyes of *Blepharocera* are plainly divided; or it may be said that there are two on each side (Pl. XVIII, figs. 1 and 2). One of these eyes is dark colored, has small facets, and faces anteriorly and laterally. It is fairly

convex. The other is reddish brown, is composed of much larger facets, faces dorsally, and has a nearly flat surface. This red, large-facetted dorsal eye has the appearance of a flattened mushroom head, or thick plate, resting above the other eye. In the males, the dorsal, large-facetted eye is much smaller and less conspicuous than in the female, but both parts of the eye (or both eyes) are plainly present. This difference in the two parts of the eye is more radical, however, than can be discovered by a mere examination from without. The ommatidia, or eye elements, of each of the regions differ, as shown by sections (see Pl. XVII, fig. 1.) in many particulars. Corresponding with the difference in size of the facets (the corneal lens of the ommatidia), there is a marked difference in the diameter of the ommatidia from the two regions. The ommatidia of the dorsal, large-facetted eye are nearly twice as wide, and they are fully twice as long, as the ommatidia of the small facetted eye. Another striking and important difference is this, the larger ommatidia are very much less strongly pigmented than the smaller ommatidia. There are, also, some differences in the character of the inner optic "layers" lying between the hypodermal portion of the eye and the brain; characters too technical for discussion here. In sum, however, it is evident that there is so marked a difference in structure between the two eye regions that there must be a difference in exercise of the function. The seeing by one of the eye regions differs from the seeing by the other eye region.

In a brief discussion elsewhere of the "divided eyes of arthropods" (Kellogg, 1898) reference has been made to the observations of Chun (1896), who has described the structure of the divided eyes of certain pelagic crustaceans, and to the observations of Zimmer (1898), who has studied the divided eyes of certain male May-flies. In both of these cases the eyes show two sizes of facets, and accompanying this are both those other structural differences which are apparent in *Blepharocera*, viz., the large ommatidia and small amount of pigment of the large-facetted eyes as compared with the small ommatidia and heavy

pigmenting of the small-faceted eyes. Here are three groups of arthropods, viz., certain crustaceans, May-flies, and flies, widely separated genetically and of widely varying habits, showing a common structural modification of the eyes. We have evidently to do with independent adaptations determined by some common functional need.

The large size of the ommatidia and the small amount of pigment are characters which adapt the large-faceted eyes for seeing in poor light (in the dark) and for readily perceiving moving objects (delicate perception of shadows). The normal, small-faceted eyes see more accurately the actual shape of visible objects; they have better definition, but require much light. Chun explains that the large-faceted eyes of the pelagic crustacea enable them to perceive their prey (for the crustacea possessing these eyes are all predaceous) in the poorly lighted levels of the water. The large-faceted eyes of the male May-flies enable them, according to Zimmer's explanation, to perceive the advancing female during the twilight marriage flight peculiar to these forms. What is the special use of the large-faceted eyes in the case of *Blepharocera*?

The females are predaceous; they capture other smaller live insects, and, lacerating them with the saw-edge mandibles and blade-like maxillæ, lap their blood. The males, on the other hand, presumably, do not capture insects; they have no mandibles, and are probably nectar-feeding. The female might advantageously be possessed of a number of those large, weakly pigmented eye elements which are specially adapted to the quick perception of moving objects. But what makes this explanation less convincing is the fact that the males also possess these large-faceted ommatidia, although, to be sure, in fewer number. Perhaps both males and females are active in twilight. Search as carefully as one might, never but very few of the adult *Blepharocera* could be found along the stream, from which they were certainly issuing by thousands. Until the habits of our fly are better known, then, it is hardly profitable to speculate on the special use of its large-faceted eyes.

Imaginal Genitalia (Pl. XXII, figs. 2, 3, 4, 5, 6, 7 and 8). The modifications of the last segments of the abdomen with their processes are marked in the different Blepharocerid species examined, and if known for all the species so far described could without doubt be advantageously used in specific, perhaps generic diagnoses. It is in the male that the more complex development of these parts, which may be called the external genitalia, takes place, and in which most difference is apparent in a comparison of species. Of the species whose genitalia the writer has examined, viz., *Blepharocera capitata*, *B. jordani* and *B. osten-sackeni*, and *Bibiocephala elegantulus*, *B. doanei* and *B. comstocki*, *Blepharocera capitata* (Pl. XXII, figs. 2, 3, 4, 5 and 6) presents the simplest type of male genitalia, and *Bibiocephala snowi* (Pl. XXII, figs. 7 and 8) the most complicated. The figures make the structure of these parts in the two species noted so obvious that a detailed description of them is unnecessary.

The other species may be grouped roughly between these two extremes, each species showing, however, its own characteristic modifications. In the female, the modifications of the segments and development of epiphyses are less marked, as shown in Pl. XXII, figs. 4, 6 and 7. The typical condition is manifest in all the species examined. The single pair of epiphyses and both the dorsal and ventral surface of the last abdominal segment bear special sense papillæ, perhaps of simple tactile function. The structure of these papillæ with their special nerve endings is shown in Pl. XXII, fig. 5.

V. HABITS OF LARVÆ, PUPÆ, AND IMAGINES.

Larvæ.—The larvæ of all the Blepharoceridæ yet known live submerged in swift-running, clear streams, which practically limits their occurrence to mountainous or at least hilly regions. They are found usually in groups of lesser or greater number in favorable spots, sometimes, as in the case of *Blepharocera capitata*, in Coy Glen, near Ithaca, New York, forming "patches" of hundreds of individuals

clinging to the smooth rock bed of the stream, with from an inch to two inches of water running swiftly over them.

In Colorado and California the larvæ of *Bibiocephala elegantulus*, *B. comstocki* and *B. doanei* and those of *Blepharocera jordanii* have been found more scattered and usually more deeply submerged; this is usually caused, or at least the other condition made impossible, by the broken condition of the stream beds, which are usually composed of separate stones of various sizes rather than of smooth bed rock. The larvæ cling firmly to the rock by means of the six ventral suckers (whose structure and mode of action is explained on p. 203), and when disturbed can hold so fast that the body is more readily torn in two than dislodged as a whole. Locomotion, which, though slowly, is freely accomplished, is in a lateral direction; the moving larva loosens the hold of three suckers at a time and swings to one side the fore or hinder half of the body thus released, the suckers again attach this part of the body in its new position, and the other half of the body is loosened and swung over, and thus a slow lateral translation of the larva takes place.

The larvæ appear to feed chiefly on diatoms, although other food is doubtless taken. The older larvæ of *Blepharocera capitata* almost always bear a dorsal, felt-like covering, which is composed of a close growth of diatoms. The most abundant diatom in this growth was one of the stalked *Gomphonema*. The basis of the covering is the gelatinous mass at the base of the stalked diatoms. Scattered upon and through this mass were individuals of *Nitzschia*, and several other diatomaceous genera. The covering has a soft, felt-like appearance, is grayish or brownish in color, and does not seem to trouble the larvæ. An examination of the alimentary canal of *B. capitata* larvæ always revealed scores or hundreds of the siliceous tests of the diatoms. Undoubtedly the larvæ live chiefly on the diatoms which live on the rocks in these swift, clear waters. The sluggish habits of the larvæ, and their restriction to parts of the stream where the only other possible food is carried swiftly

along, makes this fixed diatom supply about the only food resource. In the Colorado and California larvæ of the *Bibiocephala* species and of *Blepharocera jordanii*, the dorsal covering of diatoms is rather uncommon, though not infrequently to be seen.

Frequently the attempt has been made to bring living larvæ into the laboratory, but only when the collecting ground is very near the laboratory is this possible, and even then it is not worth while. The larvæ cannot live in stagnant or even in quiet or slow-running water. Indeed if, in the falling of the stream, larvæ get stranded in a suddenly made pool or still, quiet-water part of the stream they soon die. They must have the highly aerated, swift water of the stream's center; they like the lip of a fall, the rocks of cascades, and the sides of a pot-hole in which the water is ever whirling and boiling.

Pupæ.—The pupæ are found in the same places as the larvæ; that is, the larvæ when ready to pupate do little more than arrange themselves, almost always in small or large groups, with heads pointing down stream, and there make the last larval moult. Each pupa is fastened to the rocks by six pads, three on each lateral margin of the ventral aspect of the abdomen; these pads are not like the suckers of the larva whose hold can be voluntarily loosened, but they permanently attach the pupa to one spot. The pupa is, strongly convex above, with a dark brown or black, heavily chitinized body-wall, and is perfectly flat on its ventral aspect, which lies smoothly against the rock. The wings and legs lie folded on this ventral aspect, which is covered only by a thin, colorless, pupal cuticula. From the prothorax projects dorsally a pair of respiratory organs, each composed of four thin, double-walled plates, the outer plates of each set being strongly chitinized and acting as protecting covers for the two delicate membranous inner ones (the whole arrangement like a two-leaved book with board covers).

Of absorbing interest to the observer is the course of emergence of the adult from its submerged, fixed pupal case. Professor Comstock seems to have been the first to

watch the process carefully, and he describes it in his Manual (p. 435) as follows:—

“Each midge on emerging forced its way out through a transverse rent between the thorax and abdomen. It then worked its body out slowly, and in spite of the swift current held it vertical. The water covering the patch of pupæ varied from one-fourth to one-half inch in depth. In the shallower parts the adult had no trouble in working its way to the surface, still clinging to the pupa-skin by its very long hind legs. While still anchored by its legs, the midge rests on the surface of the water for one or two seconds and unfolds its wings; then freeing its legs it takes flight. The adults emerging from the deeper water were swept away by the current before they had a chance to take wing. The time required for a midge to work its way out of the pupa-skin varied from three to five minutes.”

As is obvious, the whole process of emergence and escape into free air must be a quick one. Usually with insects it takes some time for the proper expansion of the wings, which are, in the pupa, neither wider nor longer than the pupal wing-cases, but attain their full size only after withdrawal from these cases. But in the *Blepharocerid* there is no time for that; the slender legs cannot hold long against the beating of the swift water, and so the remarkable condition of a full development and expansion of the wings in the pupa obtains in this family. The fully developed wings lie in the pupal case folded both longitudinally and transversely, and only need to unfold to be ready to carry the fly into the safe air. It is this folding which produces the secondary veining of the wings characteristic of the family, this veining being simply the persisting creases and lines of the folding (Pl. XXI, figs. 7 and 8).

The writer has often watched the emergence of adults, and has been struck by the great loss (apparently) of life in the process. So many are swept away by the swift water before the wings can be unfolded or before the legs can be loosened from the pupal sheath, that it seems no wonder that the family is a disappearing one. It is a case of the

dangers of an extreme specialization. If the fixed pupæ lie in water too deep (easily occasioned by a sudden rise in the stream at the time for emergence), or on the other hand, become wholly bereft of the life-giving water by a falling of the stream, there is no hope for the fly. The first contingency seems indeed to be somewhat provided for (as explained in the account, *postea*, of the life-history of the flies) by the apparent power of the insect of postponing for some time, if necessary, its emergence. Thus, in the event of a heavy rain and consequent rise of the stream, the too deeply submerged pupa may lie unchanged until the water has run off (a matter which happens speedily in swift streams) to a safe shallowness.

Imagines.—The fully developed flies were found numerous in the case of but two of the six species whose larvæ and pupæ are familiar to the writer. These two are *Blepharocera capitata* (Ithaca, New York) and *Bibiocephala elegantulus* (Estes Park, Larimer County, Colorado). Abundant as the larvæ and pupæ of the Californian species are, and *Bibiocephala comstocki* and *B. doanei* are really abundant in half a dozen streams within easy reach of the laboratory, but one free-flying *B. comstocki* and but three or four *B. doanei* have been taken. Of *Blepharocera jordani*, whose larvæ and pupæ are also not uncommon in the same streams, but a single free fly has been taken. As indicated in the descriptions of the new species, it has been possible to get acquainted with the structural characters of the adults by dissecting the flies out from the pupal cases, but such methods are hardly available for a study of the habits of the flies!

The flies of *Blepharocera capitata* were seen abundant last summer (1901) on the banks of Cascadilla Creek, on Cornell University Campus (Ithaca, New York). The flies at rest cling by their long legs to the undersides of leaves on the bank, from the water's edge to eight or ten feet away. Of the hundreds of flies which were seen here in two or three visits, all were females; and the chief business on hand was feeding. This was accomplished by capturing

on the wing tiny Chironomid midges, and then returning to a leaf, where the unfortunate prey was lacerated by the long, strong, saw-like mandibles, and the blood and body juices drunk. The empty, torn skin of the prey was then dropped. As the males do not have the mandibles, they undoubtedly have a wholly different food habit (probably non-predatory), and this may account for the absence of males from this feeding ground. No indications could be found of mating or egg-laying. The flight is rather slow and weak, a sort of timid fluttering.

In the summers of 1900 and 1901 the flies of *Bibliocephala elegantulus* were seen commonly flitting about among the great boulders of the Willow Park terminal moraine, where the Big Thompson River cuts through it. The flies spent most of their time at rest on the vertical sides of the boulders from a few inches to two feet above the water's surface, but always where the rock face was frequently wetted by the spray of the dashing water. The flies rested with legs and wings outstretched and body close to the rock. The wings touched the rock face and, indeed, the attitude seemed to be adapted to bring as much of the body into contact with the wet smooth face of the rock as possible, as if to resist, by increased friction, the tendency of the fly to slide down the vertical surface. None of these flies was seen feeding, mating, or egg-laying, although many hours were spent in watching them. They were most numerous on bright, sunshiny days; on cloudy days the favorite rocks were often entirely deserted. The flight is poor, and numerous flies were caught readily in the hands.

Life-history.—The complete life-history of no Blepharocerid species is known. The eggs of no species are known, and the larvæ and pupæ of but two species not North American have been described, viz., *Philorus* (*Liponeura*) *brevirostris*, described by Dewitz and Wierzejski from Europe, and *Curipara torrentium* described by Fritz Müller from Brazil.

The immature stages of one North American species, *Blepharocera capitata*, have been known since about 1881

Riley (1881) referring briefly to the finding of larvæ and pupæ of this species in Watertown, New York, and elsewhere later in that year. Comstock (1895) describes and figures both larvæ and pupæ, and in a comparatively recent paper (Kellogg, 1900) these stages were described in detail by the writer, and an account of the life-history of the species given as far as worked out. Young larvæ (2.5 millimeters long) were found abundantly in Coy Glen (Ithaca, New York) on May 9 (1898); on May 14, in the same place, the larvæ were from 3 to 10 millimeters (full grown) long, and the first pupæ were noted; on May 17, there were many new pupæ but also still many larvæ, and these of all sizes from the smallest to the full grown ones; on May 20, the pupæ far outnumbered the larvæ; and on May 26, the larvæ were scarce. No adults had yet issued. On June 1, the flies were found issuing, and by June 9, most of the imagines had issued although there were still pupæ and even some larvæ, mostly old. By the end of June, there were no larvæ or pupæ left. On June 27 (1901), the females were found in large numbers, feeding along Cascadilla Creek (Ithaca, New York), as already described. Both of these streams (Cascadilla and Coy Glen) have been watched by Professor Comstock through the latter half of the summer and autumn but no other generation appears. How long do the imagines live? When and where are the eggs laid?

On June 22 to 25, imagines of *Bibiocephala elegantulus* were found to be numerous among the boulders of Big Thompson stream, Estes Park, Colorado (altitude 7,500 feet), where the stream breaks through the Willow Park terminal moraine. At this time, old pupæ and empty pupal skins were found, but no larvæ except two very young ones. On August 10 to 12, the flies were found still common and numerous larvæ, young and old, but no pupæ. In three other nearby mountain torrents, viz., Wind Creek, Mill Creek, and South Fork of Big Thompson, adults and old pupæ were found. A note made at this time is as follows: "It seems to me that I have got here just as the last adults

of one generation are issuing, and that the larvæ of August are larvæ from eggs laid by these adults. This would mean a generation of flies appearing about July 1, say, and a second one appearing later, say about September 15." This is, of course, mere conjecture.

Blepharocera jordani. The larvæ of *Blepharocera jordani* have been found as early as February 23 (Los Gatos Creek, California), and as late as June 1 (Stevens Creek, California), and at various times in each of the three intervening months. Pupæ were first found on April 1 (Los Gatos Creek, California), and as late as June 4 (Smith's Creek, California). These dates are derived simply from the data of collected specimens and do not indicate a systematic inspection of any single breeding place of the species. On the occasion of the June captures, the larvæ were few and the pupæ old; on June 4, at Smith's Creek, only pupæ (*i. e.*, no larvæ) were found.

Bibiocephala doanei. The larvæ of this species were taken as early as February 25 (Los Trancos Creek, California), and as late as July 26 (Red Cap Creek, Hoopa Indian Reservation, Humboldt County, California), and in all the intervening months; pupæ are first recorded March 31 (Campbell Creek, California) and from then till July 26 (Red Cap Creek, Humboldt County, California); the only free-flying imago was taken on July 15 (Congress Springs, Campbell Creek, California).

Bibiocephala comstocki. The writer's earliest recorded date of taking the larvæ of this species is February 11 (Alembique Creek, California), the latest April 30 (Stevens Creek, California); the earliest pupæ are of the date February 27 (Los Gatos Creek, California). A free-flying imago was taken April 6 (Saratoga Springs, Campbell Creek, California).

Distribution.—The Blepharoceridæ are too unfamiliar to allow us to make many generalizations yet regarding their distribution. What is known of the general distribution of

the family over the world has already been indicated in the Introduction and in the discussion of the classification of the genera. Although so few species are known, three continents are included in the range of the family, these conditions suggesting that we have to do with a family probably formerly including numerous species scattered over the world, but now dying out, a species persisting here and there through the wide range. These persisting species agree remarkably in the habits of the immature stages, and indicate in just what kind of habitat we should look for other members of the family in regions from which as yet no Blepharocerids are recorded. The larvæ and pupæ live shallowly submerged only in swiftly running, clear, fresh water; such conditions are provided by all, or nearly all, mountain or hill brooks and hardly anywhere else. As the known species extend from the equator to subarctic latitudes, temperature or climate offer probably no barriers, nor probably does altitude, the North American species ranging from nearly sea-level (*Blepharocera capitata*) to 8,000 feet (*Bibiocephala elegantulus*).

In their local distribution those Blepharocerid species of which we know anything at all nearly sufficient for speaking with confidence, offer certain strikingly contrasting conditions. *Blepharocera capitata*, for example, specimens of which come from Ithaca, New York, from Ampersand Creek in the Adirondacks, and from Riviere des Chiens, a brook flowing into the St. Lawrence about twenty miles east of Quebec, and which has been taken in three or four other localities in northeastern United States and Canada, is common in three streams, Coy Glen, Six Mile Creek, and Cascadilla Creek, near Ithaca, New York. But there are at least a dozen other streams similarly swift, clear, and with smooth rock beds, within a radius of fifteen miles of Ithaca, and in most of these Professor Comstock and his students or the writer have looked for the species in vain. On the other hand, *Bibiocephala comstocki*, *B. doanei*, and *Blepharocera jordani*, first found by the writer in Los Gatos and Campbell creeks, near Stanford University, have since

been found in practically every one of the other eight or nine neighboring similar mountain streams which run down from the Santa Cruz and Santa Morena mountains eastward into the northern end of the Santa Clara Valley. And across the valley, fifty miles away to the south and east, the writer found two of these species in a stream (the Coyote) running from the Coast Range westward into the valley. Beyond, however, the mere facts of this contrasting local distribution, nothing can be offered here; we have not fairly begun to understand these strange and absorbingly interesting flies.

VI. WORK TO BE DONE.

As this paper has been cast in its present form chiefly for the sake of serving as a sort of introduction to the study of the Blepharoceridæ by American students, this end will certainly only be furthered by calling specific attention to the most apparent desiderata in the knowledge of this group.

First, there are more species to be found in this country; wherever there are mountains or hills with swift, clear streams, it is safe to assert that Blepharoceridæ will be found there. Dipterologists have spoken to the writer of the rarity of these flies; but in an inspection of the region within twenty miles of his laboratory, every stream of a dozen was found to be invaded by the family, and in two years of unsystematic search as many more species have been added to the North American fauna as have been recorded since the first *Blepharocera capitata* was found in 1881. On a pleasure trip to Colorado, the four streams near the camping ground were all found inhabited by Blepharocerids; and in a careless stroll along the banks of the St. Lawrence, near Quebec, the characteristic larvæ were seen in the first brooklet peered into! Let the streams of the Ozarks, the Georgia hills, the Tennessee and North Carolina mountains, the Cascades and Olympics of the Puget Sound region, the Rockies of New Mexico and Arizona, and the mountains of Southern California be looked into.

With additional species and a widened distribution of old forms known, the classification can be revised and satisfactorily founded.

The life-history of no Blepharocerid species is fully known; the first eggs of any species are yet to be found; the food-habits of the males are unknown; a host of observations on the habits are to be made.

No one has studied the "secondary venation," the creasing of the wings. Are these lines of folding uniform in the species, genus, family? Are there classificatory characters to be derived from them? What is the significance of the little chitinous thickening or knot in the re-entrant angle of the anal margin of the wing?

Do the well developed and plainly differing external genitalia, especially those of the males, offer characters which can be used in classification? The writer is practically sure of this, and would have attempted to use them in the descriptions and analytical tables, only that nothing was known about them in the North American species previously described, and not yet seen by him.

NOTE.—The writer may add that he should like to have the opportunity to do some of this needed work, and to that end will be grateful for any sending of specimens, with full data, of larvæ, pupæ, or imagines of any species of Blepharocerid.

STANFORD UNIVERSITY,
CALIFORNIA,
November, 1902.

LITERATURE CITED.

1901. BEZZI, M. *Hapalothrix lugubris*. *Zeit. f. Hym. u. Dipt.*, Vol. I, pp. 275-278.
1896. CHUN, CARL. Atlantis, Biologische Studien über pelagische Organismen, *Bibliotheca Zoologica*, Bd. VII, Heft. 19.
1895. COMSTOCK, J. H. Manual for the Study of Insects, pp. 432-436. Ithaca, N. Y.
1880. DEWITZ, H. Beschreibung der Larve u. Puppe von *Liponeura brevirostris* Loew. *Berliner Ent. Zeit.*, Vol. XXV, pp. 61-66, Pl. IV.
1898. KELLOGG, V. L. The Divided Eyes of Arthropoda. *Zool. Anzeiger*, Bd. XXI, pp. 280-281.
1900. ——— Notes on the Life-history and Structure of *Blepharocera capitata* Loew. *Entomological News*, Vol. XI, pp. 305-318.
- 1900a. ——— A New *Blepharocera*. *Psyche*, Vol. IX, p. 39.
1902. ——— The Development and Homologies of the Mouth-parts of Insects. *Amer. Nat.*, Vol. XXXVI, pp. 683-706, 26 figs.
1881. MÜLLER, FRITZ. A Metamorphose de um Insecto Diptero. *Archivos do Museu Nacional do Rio Janeiro*, Vol. IV, pp. 47-58, Pls. IV-VII.
1895. OSTEN-SACKEN, C. R. Contributions to the Study of the *Liponeuridae* Loew (*Blepharoceridae* Loew, olim). *Berliner Ent. Zeitschr.*, Bd. XL, pp. 148-169.
1881. RILEY, C. V. Note on *Blepharoceridae*. *American Naturalist*, Vol. XV, pp. 438-447, 1 plate.
1890. VON RÖDER, V. *Wien. Ent. Zeitung*, Vol. IX.
1881. WIERZEJSKI. O przeobrazeniu muchy *Liponeura brevirostris* Loew. Krakow.
1898. ZIMMER, CARL. Die Facettenaugen der Ephemeriden. *Zeit. f. wiss. Zool.*, Bd. LXIII, pp. 236-262, Pls. XII-XIII.

EXPLANATION OF PLATE XVIII.

Blepharocera jordani, sp. nov.

Fig. 1. Head of male.

Blepharocera osten-sackeni, sp. nov.

Fig. 2. Head of male.

Bibiocephala doanei KELLOGG.

Fig. 3. Head of male.

Bibiocephala elegantulus VON RÖDER.

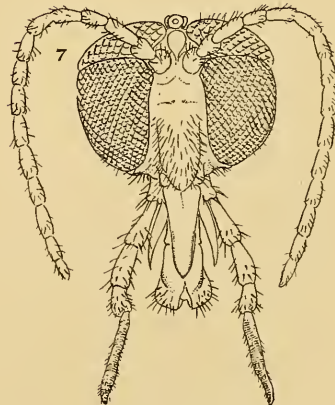
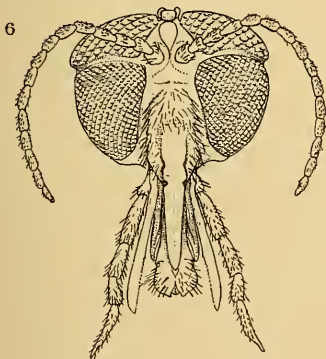
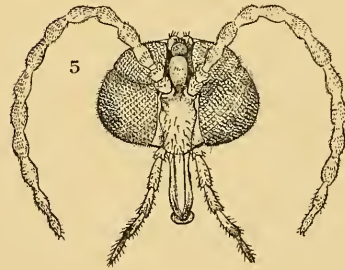
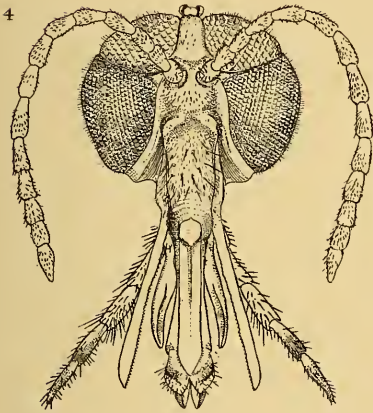
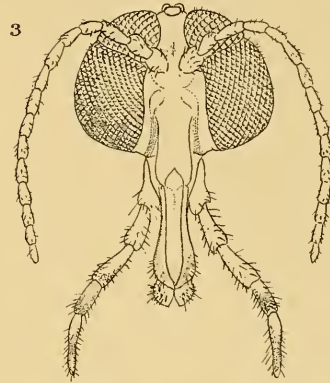
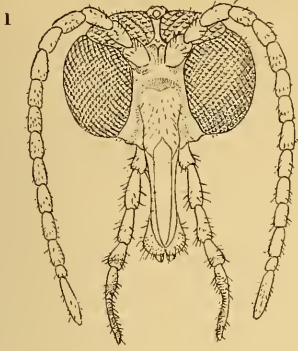
Fig. 4. Head of female.

Fig. 5. Head of male.

Bibiocephala comstocki, sp. nov.

Fig. 6. Head of female.

Fig. 7. Head of male.



EXPLANATION OF PLATE XIX.

(Only the primary or true venation shown; the secondary venation, or lines of folding, omitted.)

Blepharocera fasciata LOEW.

Fig. 1. Wing (after Loew).

Blepharocera osten-sackeni, sp. nov.

Fig. 2. Wing (from specimen).

Blepharocera jordani, sp. nov.

Fig. 3. Wing (from specimen).

Bibliocephala doanei KELLOGG.

Fig. 4. Wing (from specimen).

Bibliocephala elegantulus VON RÖDER.

Fig. 5. Wing (from specimen).

Bibliocephala comstocki, sp. nov.

Fig. 6. Wing (from specimen).

Bibliocephala grandis OSTEN-SACKEN.

Fig. 7. Wing (after Osten-sacken).

Philorus bilobata LOEW.

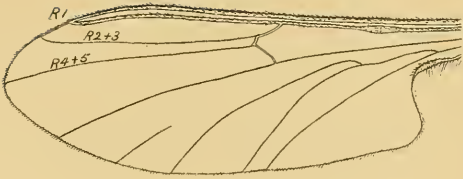
Fig. 8. Wing (after Loew).

Philorus yosemite OSTEN-SACKEN.

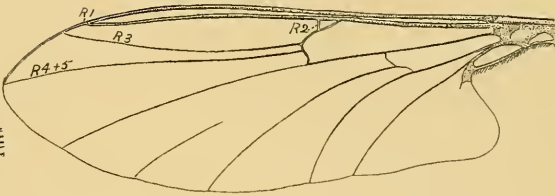
Fig. 9. Wing (Diagram made from description of Osten-Sacken).



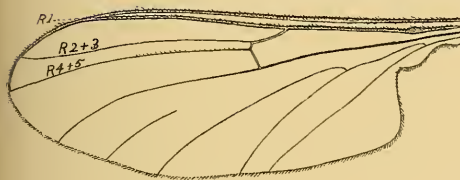
1



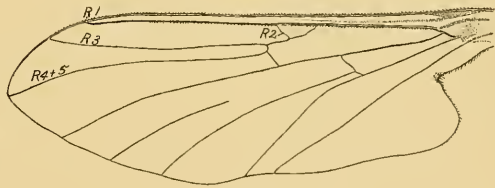
2



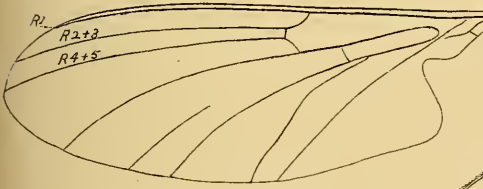
4



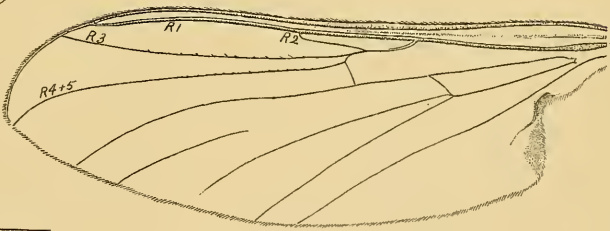
3



5



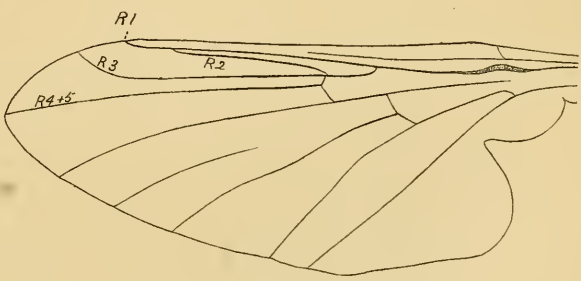
8



6



9



7

EXPLANATION OF PLATE XX.

ant., antenna; *l. p.*, lateral process; *t. g.*, tracheal gills; *s.*, sucker.

Blepharocera jordani, sp. nov.

Fig. 1. Larva, dorsal aspect.

Fig. 2. Larva, ventral aspect.

Blepharocera osten-sackeni, sp. nov.

Fig. 3. Larva, dorsal aspect.

Fig. 4. Larva, ventral aspect.

Bibliocephala comstocki, sp. nov.

Fig. 5. Larva, dorsal aspect.

Fig. 6. Larva, ventral aspect.

Bibliocephala doanei KELLOGG.

Fig. 7. Larva, dorsal aspect.

Fig. 8. Larva, ventral aspect.

Bibliocephala elegantulus VON RÖDER.

Fig. 9. Larva, dorsal aspect.

Fig. 10. Larva, ventral aspect.

Fig. 11. Larva from Colorado, unknown species; dorsal aspect.

Fig. 12. Larva from Colorado, unknown species; ventral aspect.

